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The Return-Risk Tradeoffs Associated with Processing Tomato Production in Northwestern Ohio

BRYAN W. SCHURLE

BERNARD L. ERVEN

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
U. S. 250 and Ohio 83 South
Wooster, Ohio

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BRYAN W. SCHURLE and BERNARD L. ERVEN[2]

INTRODUCTION

This study concentrates on a major factor influencing the future of the processing tomato industry in Ohio. The factor is the farm level competitive position of tomatoes when both return and risk are considered. Processing tomatoes compete directly with corn, soybeans, and wheat in northwestern Ohio. Tomatoes are typically a higher return enterprise than the grain crops, but the increased risk of tomato production must also be considered. Net return-risk tradeoffs are central to farm enterprise choice decisions between high return, high risk enterprises such as tomatoes and relatively low return, low risk enterprises such as grain crops. Providing data for decision making relative to these tradeoffs is the central objective of this study.

Two specific issues will be considered. The first deals with development and analysis of farm plans which include specialty crops in addition to the traditional grain crops. This involves a comparison of individual enterprises as well as combinations of enterprises which provide the "best" use of farm resources. Specifically, the potential for additional returns, the effects of diversification, and the increase in risk as tomatoes are added to the farm plan are critical issues to farmers interested in this enterprise.

The second issue of much concern in the tomato industry is the choice between hand and machine harvesting. The returns and risks associated with the two alternative harvesting methods are directly related to decisions about their use.

STATUS OF THE TOMATO INDUSTRY

Ohio is second to California in the production of processing tomatoes with approximately 7% of the 1976 U. S. acreage. The total value of Ohio processing tomatoes produced in 1976 was more than $34 million from 22,300 acres. In 1976, the counties indicated in Figure 1 contributed more than half of the total processing tomato acreage in the Midwest Region of the U. S., while east-central Indiana contributed an additional 32%. The Midwest has maintained its relative share of United States production at approximately 15%, but California has increased its share from 56% in 1965 to about 78% in 1976, mostly at the expense of the East and minor producing states (8, 18, 19).

The extensive use of irrigation and a favorable climate in California allow uniform plant growth and substantial control over the environment during harvesting. This has resulted in nearly all of the California production being harvested mechanically. Wet conditions during harvest in most other producing areas reduce the economic advantages of mechanical harvest. The economic advantages of mechanical harvest have contributed greatly to California's continued dominance in the processing tomato industry. However, the Midwestern and Eastern producing areas have the advantage of location near the large Eastern population centers.

Ohio tomato producers must also consider other crop enterprises such as corn, soybeans, wheat, and particularly cucumbers. There is a complementary relationship between tomatoes and cucumbers in the employment of migrant farm workers. Practically all of the Ohio cucumber production is hand harvested by migrant workers, resulting in a much greater yield and higher quality product than would be the case with mechanical harvest. Hand harvest of tomatoes begins immediately after termination of the cucumber harvest. Other crops such as corn, wheat, and soybeans exhibit a competitive relationship with tomatoes.

The total acreage and farm product value of tomatoes and cucumbers seem insignificant when compared to the total Ohio acreage and product value of corn, soybeans, and wheat (Table 1). Yet for those farms with these specialty crops and those northwestern Ohio farms searching for enterprises which will increase net returns to management, labor, and capital, these specialty crops are a major concern.

Budgeted profit and return to management for each of the crops is summarized in Table 2. These figures are estimates used for budgeting purposes only. However, the table does show the approximate relationships in terms of expected profit and return to management. One important aspect which is not

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[2]Bryan W. Schurle, former research associate at the Ohio Agricultural Research and Development Center, is an Assistant Agricultural Economist with the Kansas Agricultural Experiment Station, Kansas State University. Bernard L. Erven is Professor and Associate Chairman, Dept. of Agricultural Economics and Rural Sociology, The Ohio State University and Ohio Agricultural Research and Development Center.

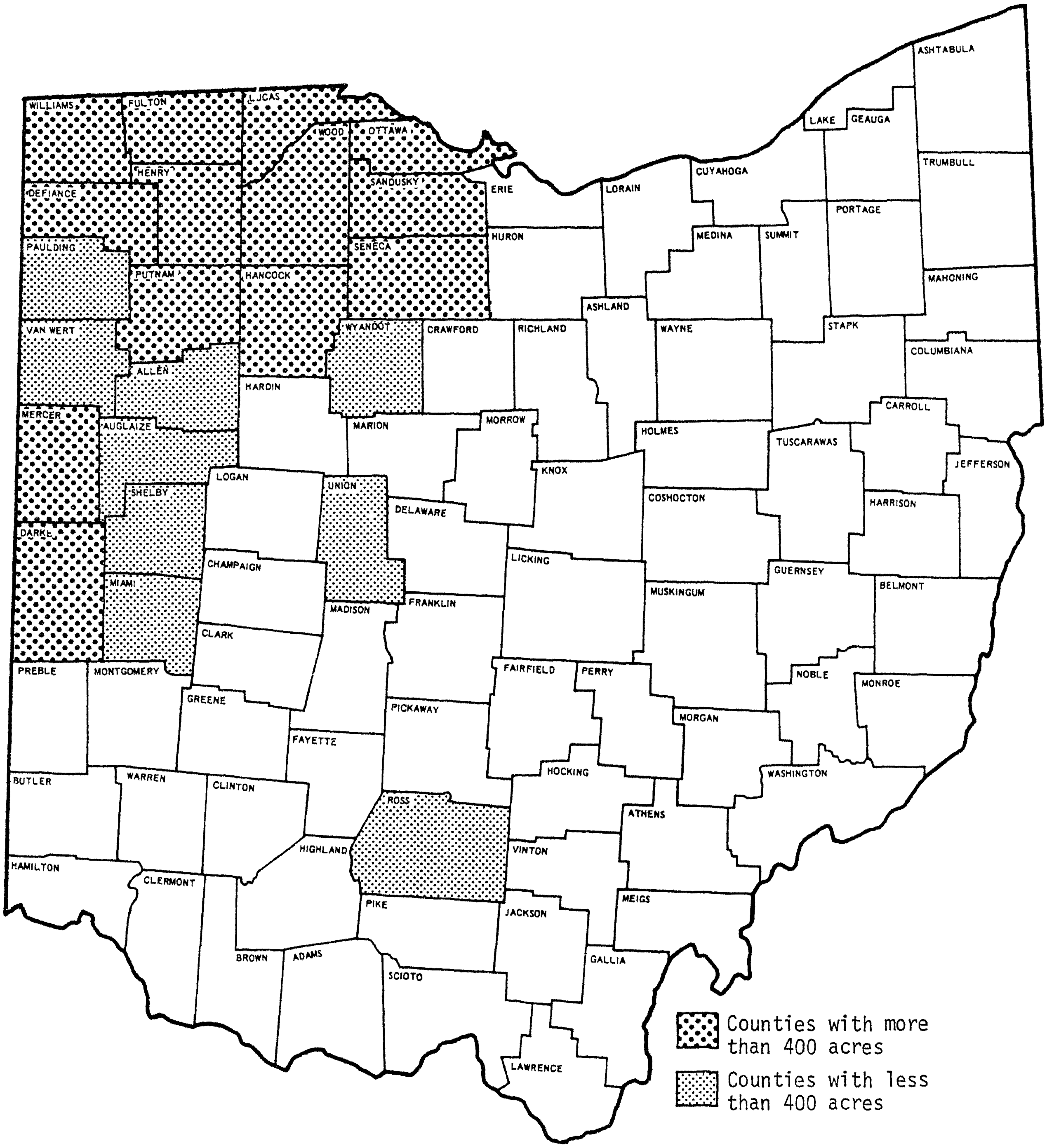

FIG. 1.—Processing tomato acreage in Ohio by county, 1976.

Source: Ohio Processing Vegetables, Ohio Crop Reporting Service, Columbus, released Dec. 21, 1976.

TABLE 1.—Ohio Acreage, Yield, and Total Value of Production, Grain and Specialty Crops, 1976.

	Acreage (000)	Yield/Acre	Total Value ($ Million)	Average Total Value per Acre
Processing Tomatoes	22.6	23.3 T.	34.4	$1,518
Processing Cucumbers	6.3	10.8 T.	9.7	$1,540
Corn for Grain	3,920	101.0 Bu.	910.6	$ 232
Wheat	1,650	40.0 Bu.	194.7	$ 118
Soybeans	2,880	32.5 Bu.	631.8	$ 219

Source: Vegetables-Processing, 1976 Annual Summary, Dec. 16, 1976, SRS, USDA; Crop Production, 1976 Annual Summary, Jan. 17, 1977, SRS, USDA; Ohio 1976 Annual Summary of Crop Production and Value, Jan. 26, 1977, SRS, USDA.

shown in this table is the risk which accompanies the production of tomatoes and cucumbers.

Tomato Production Technology

Several recent advances in tomato production technology are promising, yet not widely adopted. The most important advance of the last 10 years is the development of the mechanical harvester and associated cultural practices into a viable alternative to hand harvest. Mechanical harvesters were first used in Ohio in 1968. A wave of enthusiasm followed, and the harvester was hailed as the answer to many labor problems. The number of machines and acres harvested by machine climbed steadily until 1971 when 9.7% of the Ohio tomato acreage was harvested mechanically (4). The enthusiasm for mechanical harvesters waned in 1973 and 1974, resulting in a slight decrease in the number of mechanical harvesters. However, weather conditions allowing successful mechanical harvest in 1975 and 1976 added impetus to the growth in acreage harvested by machine. In 1976, more than 16% of the processing tomato acreage was harvested by machine (19).

The choice between hand and mechanical harvest is influenced by several factors. Although there is presently an adequate supply of migrant labor, government regulations coupled with already existing labor management difficulties are causing some farmers enough problems to consider alternatives to hand harvest (3). However, there is also concern over the risk of mechanically harvested tomatoes. A wet period during harvest may prevent the operation of a mechanical harvester, resulting in great financial loss. This situation is basic to the enterprise selection problem being considered in this study.

RISK AND ENTERPRISE CHOICE

Making decisions under risk is now widely recognized as a major problem confronting the management of many farms (1). Farmers are uncertain of the future states of weather, technology, input prices, yields, output prices, and government policy.

A common concept of risk revolves around the concept of "possibility of loss." An understanding of the relationships between this concept of risk and the statistical measures of risk used in this study is important. Variability of returns as measured by the standard deviation of returns is used to measure risk. However, variability by itself does not truly measure the possibility of loss. The expected return is also very important in determining the possibility of loss for an enterprise. The coefficient of variation (standard deviation divided by expected return) is a measure which combines both variability and expected return into a measure of risk per dollar of expected return. This measure can be used to compare individual crops or farm organizations.

Tomatoes and cucumbers are more risky than grain crops. Table 3 shows the expected return above variable cost, the standard deviation of return, and the coefficient of variation for tomatoes, cucumbers, and grain crops. These figures were calculated

TABLE 2.—Budgeted Profit and Return to Management for Six Crops in Ohio, 1976 and 1977.

	Corn	Soybeans	Wheat	Processing Tomatoes Harvest: Hand	Processing Tomatoes Harvest: Machine	Processing Cucumbers
1976	$84	$ 7	$11	$235	$454	$143
1977	$65	$20	$—2	$219	$420	$—24

Source: 1976 and 1977 Ohio Crop Production Budgets.

TABLE 3.—Price, Yield, Expected Net Return, Standard Deviation of Net Return, and Coefficient of Variation, by Enterprise.

	Corn	Soybeans	Wheat	Mechanically Harvested Tomatoes	Hand Harvested Tomatoes	Cucumbers
Price	$2.50/bu	$5.50/bu	$3.25/bu	$63.00/T	$63.00/T	NA
Yield	112 bu/A	38 bu/A	50 bu/A	20 T/A	20 T/A	NA
Expected Net Return	$172/A	$122/A	$90/A	$561/A	$303/A	$250/A
Standard Deviation of Net Return	$50	$39	$28	$344	$268	$272
Coefficient of Variation	0.29	0.32	0.31	0.61	0.88	1.09

Source: Ohio Crop Budgets and time series data from individual farms.

from 8 years of data for three farms in northwestern Ohio. The standard deviations measure the differences in variability among the enterprises. Mechanically harvested tomatoes had the highest standard deviation of returns, followed closely by cucumbers and hand harvested tomatoes. The grain crops have considerably lower standard deviations and lower expected returns.

The coefficient of variation for each of the enterprises provides a measure of the risk per dollar of expected return. A comparison of the coefficients shows that cucumbers are most risky. The grain crops have lower coefficients than the tomato enterprises. Even though mechanically harvested tomatoes have greater return variation than hand harvested tomatoes, the higher expected return for mechanically harvested tomatoes results in a lower coefficient of variation for mechanically harvested tomatoes than for hand harvested tomatoes. These coefficients were calculated assuming equal yields for the two harvesting methods. A 2-ton yield advantage for hand harvested tomatoes reduces the coefficient to 0.70 and a 4-ton advantage reduces the coefficient to 0.58, which is lower than the coefficient for mechanically harvested tomatoes.

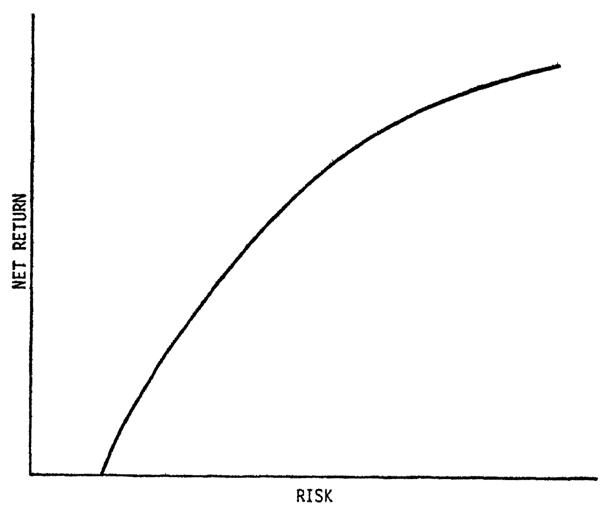

FIG. 2.—Hypothetical efficiency frontier.

This information about the risk of individual enterprises helps explain the enterprise choice problems farmers face. However, the basic question addressed in this study is how these enterprises can be combined to minimize risk for a given level of return. Minimizing risk through enterprise diversification is possible if the enterprises have different patterns of annual yield and price variations (7, 15). In a given year, one crop may do very well and offset another crop which does poorly. This reduces variation in total returns, thus reducing risk for the total farm.

A set of minimum risk farm plans can be developed. The farm plans are generated by setting various return levels and then finding the combination of enterprises which minimizes risk for the representative farm at each of the return levels. The resulting risk and return combinations can be plotted to develop an efficiency frontier (Figure 2). This same approach has been used in analyzing risk of various investment portfolios where the same type of questions is being addressed as in this study—what combination of investments minimizes the risk for a given level of return (11). Given an efficiency frontier, a decision maker can choose a farm plan (return-risk situation) which is consistent with his risk preference and goals (14). Choosing a farm plan off the frontier results in an increase in risk with no compensating increase in return, or a decrease in return with no compensating decrease in risk.

DESCRIPTION OF THE MODEL

The basis for the analysis is a linear programming model of a representative farm in northwestern Ohio. The model was designed to represent a farm which has the labor and machinery complement to efficiently and profitably produce corn, soybeans, and wheat on 600 crop acres. Costs for specialized tomato production machinery are considered variable costs for the analysis.

The information needed to model the enterprise selection problem and the data to support the analysis came from various sources. The data incorporated in the linear programming model came from research publications (2, 5, 9, 10, 12, 20) and extensive interviews with farmers, processors, machinery dealers, horticulturists, agricultural engineers, plant pathologists, and entomologists. The time series data on individual farm yields needed for the risk analysis were collected from the Ohio Farm Business Analysis data bank and from individual farm records supplied by processors.

Each of the enterprises in the study is represented by activities in the model. The corn, soybean, and wheat portion of the model was derived from the Ohio Crop Model. It is similar to the Purdue Crop Model which has been used extensively by individual farmers for farm planning (13). The tomato and cucumber activities were developed especially for this study. Activities were also included for hiring labor, land preparation, and other support services. The constraints of the model included land, labor, machinery capacity, and field time associated with critical spring planting and fall harvesting periods. It was assumed that capital was not a limiting resource.

Mechanically Harvested Tomato Activities

A group of 13 activities represents mechanically harvested tomato alternatives. The activities include both direct seeded and transplanted acreage. Six activities represent direct seeded acreage harvested mechanically and seven activities represent transplanted acreage harvested mechanically. This number of activities was required to model the activities in four possible planting periods and four possible harvesting periods. Some of the combinations of planting and harvesting periods were not considered for economic or horticultural reasons.

Table 4 shows the tomato planting and harvesting periods as well as the associated yields on heavy soil. These yields are maximum expected yields possible under good growing conditions and excellent management. The analysis is with a maximum yield for the prime planting and harvesting period adjusted down to 20 tons per acre. Under this adjustment, the yield penalties for harvesting before the last period are as shown in Table 4. This often results in an average yield of approximately 18 tons per acre. Throughout this report, quoted yields refer to the maximum yield obtained during the prime planting and harvesting period.

There is generally more concern with the feasibility of mechanical tomato harvest on heavy soils than on light soils because of more serious production problems on heavy soils. But, both heavy clay soils and light sandy soils are major soil types in the processing tomato region of Ohio. Each soil type has distinct characteristics which play a role in the decision to mechanically harvest (16). The analysis in this study will deal with heavy soils. If mechanical harvest systems are shown to be feasible on heavy soils, there is little doubt about their feasibility on light soils if some relatively minor cultural adjustment are made.

The model's land preparation activities required for mechanically harvested tomato acreage include plowing, working twice, and forming into beds in the fall.

Each tomato activity requires labor, field time, and tractor time in spring for planting and cultivating. Labor requirements in the spring are met by the operator and hired part-time labor as needed. All acreage is cultivated twice, once 2 weeks after planting and once 4 weeks after planting.

Direct seeding practices can be used on acreage for either hand or machine harvest. However, it was assumed that replanting direct seeded acreage with transplants will be necessary on 50% of the direct seeded acreage because of problems with dry weather,

TABLE 4.—Maximum Expected Mechanically Harvested Tomato Yields on Heavy Soil for the Representative Farm, by Planting Method, Planting Period, and Harvesting Period.

Planting Method and Period	Harvesting Period			
	August 10-19	August 20-29	August 30 - Sept. 12	Sept. 13-26
	(Tons per Acre)			
Direct Seed:				
April 26 - May 2	NA*	21.0	26.5	28.0
May 3 - 9	NA	NA	25.5	27.0
May 10 - 16	NA	NA	NA	26.5
Transplant:				
May 10 - 16	17.5	23.5	27.5	28.0
May 17 - 23	NA	22.5	26.5	27.0

*Not applicable.
Source: Based on estimates by Eugene Wittmeyer, Dept. of Horticulture, The Ohio State University and Ohio Cooperative Extension Service.

wet weather, frost, and wind. It is assumed that this acreage is replanted 2 weeks after initial planting. A three-row planter with the capability of dropping an anti-crustant over the seed was assumed for direct seeding tomatoes. This is one of the latest technologies available for combating the crusting problem on heavy soils.

Four time periods in the model provide the critical fall periods for harvesting tomatoes (Table 4). The total harvest period modeled stretches from August 10 through Sept. 26. It was assumed that 26 days of this 48-day session are fit for harvesting tomatoes with a mechanical harvester and that the operator and crew of the machine work 10 hours per day. Each acre of tomatoes requires 2.22 hours of harvesting time in the model. These figures restrict the harvesting capacity to that of an average size self-propelled harvester.

Each tomato activity has a restriction on the tonnage that can be delivered in the glut of the last three harvesting periods. These restrictions are specified by delivery quotas in processor-grower production contracts. The first harvesting period is unrestricted because quotas are enforced only during times of glut. Delivery quotas among processors range from approximately 0.6 ton per acre per day to 1 ton per acre per day. The effect of different delivery quotas is investigated but a 1-ton per acre per day delivery quota was assumed for much of the analysis. As an example, for a 70-acre contract with a 1-ton per acre per day delivery quota, the farmer would be allowed to deliver 70 tons per day during the last three periods of the model.

Hand Harvested Tomato and Cucumber Activities

Five activities represent tomatoes harvested by hand. Two of these activities are for transplanted acreage and three for direct seeded acreage. For hand harvested tomatoes, only different planting periods are modeled. Harvesting periods are not modeled because of multiple pickings of the same acreage. Table 5 shows yield by planting method and date for each of the five hand harvested tomato activities. Except for harvest, these activities have the same resource requirements as mechanically harvested tomatoes. The harvesting requirements for hand harvested tomatoes were not modeled because it is unlikely that hand harvest tomato acreage would be constrained by the tractor, wagon, and truck requirements or operator time during the harvest period.

TABLE 5.—Maximum Expected Hand Harvested Tomato Yields in Tons per Acre for the Representative Farm by Planting Method, Planting Period, and Soil Type, Heavy Soil.

Planting Method and Period	Yield T/A
Direct Seed:	
April 26 - May 2	28
May 3 - May 9	27
May 10 - May 16	26.5
Transplant:	
May 10 - May 16	28
May 17 - May 23	27

Source: Based on estimates by Eugene Wittmeyer, Dept. of Horticulture, The Ohio State University and Ohio Cooperative Extension Service.

The major requirement for hand harvest is migrant farm workers. For much of the analysis, it is assumed that a sufficient number of workers could be hired at the given wage rate to complete the harvest. However, some analysis is done with the assumption of no labor available for hand harvest. This assumption reflects the longer run possibility of all or most tomatoes necessarily being harvested mechanically because of problems with recruitment, employment, and cost of seasonal workers.

Another group of five activities was developed to represent tomatoes harvested by hand but grown in conjunction with processing cucumbers. This is a common practice because it allows more efficient use of migrant labor. The norm is employment of one migrant worker for 2 acres of tomatoes and 0.5 acre of cucumbers. The model forces a tomato to cucumber acreage ratio of 4:1 on the total hand harvested tomato acreage of these five activities. The activities are identical with the previously mentioned hand harvested tomato acreage activities in all aspects except for the link with cucumber acreage.

The model also contains three cucumber activities linked to hand harvested tomato production. Each corresponds to a different planting period. Cucumber planting was modeled in three 1-week periods between May 17 and June 6. It is assumed that period of planting does not affect net return per acre. Cucumber harvest was not modeled because of very limited competition from other crops for resources during the usual cucumber harvesting period.

The MOTAD Model

The linear programming model was the foundation for the MOTAD model used to analyze risk in this study (6). The MOTAD model formulation used in the study was:

$$(1)\ \text{minimize} \sum_{h=1}^{s} \bar{y}_h$$

subject to:

$$(2)\ \sum_{j=1}^{n} (c_{hj} - g_j)\, x_j + \bar{y}_h \geq 0$$

$$(\text{for } h = 1, 2, \ldots, s)$$

and

$$(3) \quad \sum_{j=1}^{n} f_j x_j = I \qquad \text{(for } I = 0 \text{ to unbounded)}$$

$$(4) \quad \sum_{j=1}^{n} a_{ij} x_j \leq b^i \qquad \text{(for } i = 1, 2, \ldots, m)$$

$$(5) \quad x_j, \bar{y}_h \geq 0 \qquad \text{(for all } h, j).$$

where:

$\bar{y}_h$ = absolute values of the negative total gross margin deviations
c_{hj} = the gross margin (gross revenue per acre — variable costs per acre) for the $_j$th activity on the $_h$th observation
g_j = the average gross margin for the $_j$th activity
x_j = the level of the $_j$th activity (usually in acres)
f_j = the expected gross margin of the $_j$th activity
I = the expected net income
a_{ij} = the technical requirements of the $_j$th activity in the $_i$th constraint
b_i = the $_i$th constraint level
s = the number of years
n = the number of activities in the basic LP model
and
m = the number of constraints in the basic model.

This model minimizes risk for each level of I (total returns above variable costs) specified in equation 3. The model minimizes risk as measured by the sum of the absolute values of the negative net return deviations ($\bar{y}_h$). Essentially this minimizes variance of returns to the farm measured by the estimator of variance

$$D \left[\frac{\pi s}{2(s-1)} \right]^{1/2}$$

where s is the number of years in the sample and D is the estimated mean absolute deviation in returns to the farm (18). In order to minimize risk while achieving a specified return level, the model selects enterprise combinations that are least risky (as measured by standard deviation in annual returns) and/or that have negatively correlated returns. Return to the farm (I) is parameterized resulting in a minimum risk farm organization for each specified level of return.

RISK ANALYSIS AND ENTERPRISE CHOICE

In this section, optimum farm plans for the representative 600-acre farm are developed for several different sets of basic assumptions. Yields and enterprises allowed to enter the solution are varied. For each set of assumptions, the key question is the trade-off between risk and net return and the change in farm plans as risk and net return change.

In the first group of farm plans, all enterprises can enter the solution and a 20-ton per acre tomato yield is assumed. (As discussed previously, the 20-ton yield assumption is the maximum yield obtained during prime planting and harvesting periods. The average yield over all acreage is approximately 2 tons less than the stated yield.) The price, yield, return, and variation data for the first group of farm plans are shown in Table 3.

Figure 3 and Table 6 present the first efficiency frontier and associated farm plans. Each point on the frontier represents a minimum risk farm organization for the corresponding level of net return. A net return of $80,000 is the smallest on the figure because farm organizations for net returns below this level have large acreages rented out.

The net return data need to be interpreted with care. Net return is return to fixed costs of machinery (excluding specialized tomato production equipment which is translated into variable costs), capital investment in land, and operator labor and management. Perspective is gained by considering the fixed costs of machinery and the return on the owner's capital investment in land. Consider the following scenario:

Return above variable costs	$120,000
Less	
Opportunity cost of capital in land ($1,500/acre at 8%)	$ 72,000
Less	
Fixed cost of machinery ($125,000 investment at 20%)	$ 25,000
Return to labor and management	$ 23,000

This suggests that approximately $100,000 should be subtracted from the returns listed in tables to arrive at an appropriate return to operator labor and management.

The slope of the efficiency frontier decreases as net return increases, indicating that the additional risk per dollar of additional net return increases as net return increases. Two factors explain this relationship between net return and marginal risk. First, the revenue variabilities for tomatoes and cucumbers are larger than those for grain crops. Thus, as specialty crop acreage increases, the marginal risk increases. Secondly, as net returns increase, enterprise selection is increasingly restricted to relatively high return crops. Consequently, the reduced opportuity for diversification results in increasing marginal risk.

Table 6 provides the standard deviation, coefficient of variation, and farm organization for each solution point on the efficiency frontier. A comparison

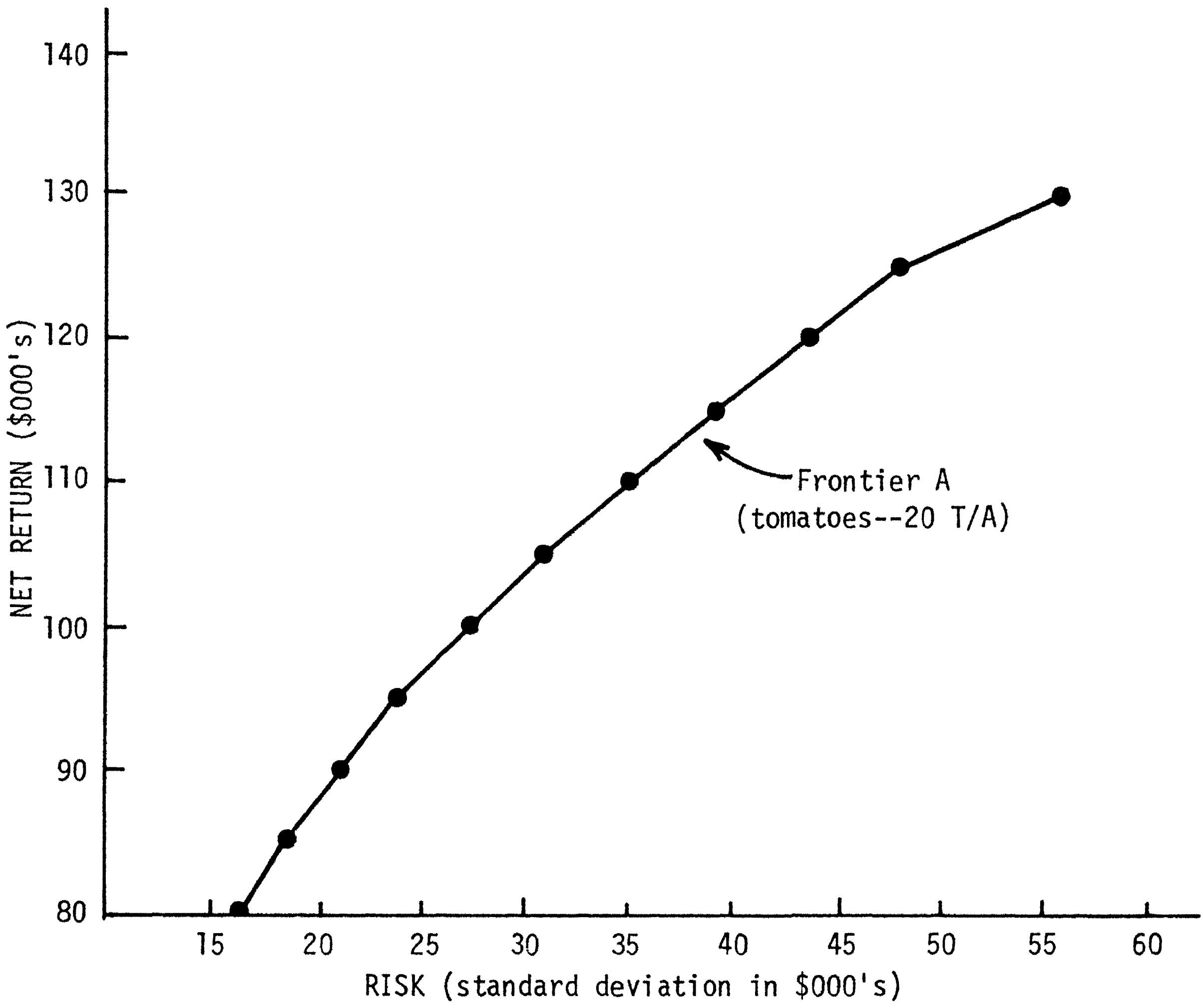

FIG. 3.—Efficiency Frontier A (tomatoes—20 T/A) for least risk farm organizations in Table 6.

TABLE 6.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier A (Tomatoes—20 T/A), Figure 3, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	130
Standard Deviation ($000's)	17	19	21	24	27	31	35	39	43	48	56
Coefficient of Variation	0.21	0.22	0.23	0.25	0.27	0.29	0.32	0.34	0.36	0.38	0.43
Farm Organization in Acres:											
Corn	210	221	187	186	245	245	273	341	445	437	483
Soybeans	116	144	223	274	278	302	262	172	70	75	0
Wheat	226	230	164	99	33	0	0	0	0	0	0
Mechanically Harvested Tomatoes	0	0	0	0	0	15	28	27	39	72	85
Hand Harvested Tomatoes	0	4	21	33	35	31	30	48	37	13	26
Cucumbers	0	1	5	8	9	8	8	12	9	3	6
Rented Out	48	0	0	0	0	0	0	0	0	0	0

of the coefficients of variation provides a relative measurement of the risk differences among the farm organizations. The coefficients show that risk per dollar of expected return increases over the entire frontier. The increase in marginal risk can be seen in the increasing intervals between the coefficients of variation as net return increases.

The acreage of individual crops varies considerably in farm organizations along the frontier. There is a clear relationship between risk and both the acreage of specialty crops and the method of tomato harvest. For the two plans with net returns below $90,000, there is no practical acreage of tomatoes and cucumbers. As net returns range from $90,000 to $115,000, acreages in hand harvested tomatoes and corn increase, while wheat acreage decreases. Soybeans are the most important grain crop in this net return range. The most important characteristic of the plans in this range is the feasibility of hand harvested tomatoes in combination with cucumbers. These hand harvested crops provide a medium risk alternative to the lower return grain crop plans and the higher return plans with mechanical harvest of tomatoes. Cucumbers enter the farm plans because they are more profitable than corn. There are also some labor benefits when the two crops enter simultaneously.

There is no practical acreage of mechanically harvested tomatoes until a return level of $120,000. Less than approximately 30 acres of mechanically harvested acreage is impractical because of the fixed costs of the mechanical harvester and other equipment. In the highest return farm plan, mechanically harvested tomato acreage reaches what processors and farmers generally consider to be a maximum acreage for one machine. Hand harvested tomatoes and some cucumber acreage are a part of these high return, high risk plans. This reflects some benefits to the farmer of diversifying within the specialty crop alternatives.

In the highest return farm plans, corn plays a major role. It is a higher return alternative than either soybeans or wheat and at this high return level, diversification within the grain crops will not attain the high return levels.

The last point on the frontier and corresponding farm plan is the same as the linear programming solution which is the maximum return level with the resources on the representative farm. With this plan, there is specialization in corn, tomatoes, and cucumbers. Such a high return, high risk plan is unlikely to be found in practice. However, plans not greatly different from this plan are quite practical and are found in northwestern Ohio.

Effects of Yield on Tomato Acreage

It is generally assumed in the tomato industry that the quality of a farmer's management directly affects his success with the enterprise and thus its role in an optimum farm plan. Quality of management is not readily measured. However, in the tomato enterprise, average yield is a reasonably good measure of management ability and therefore is used in this study.

It was assumed that risk, as measured by variance, did not vary with management level. All parameters other than tomato yield were held constant including corn, soybean, wheat, and cucumber returns. Only the direct cost of harvesting the larger volume of tomatoes changed with a change in tomato yield.

The result of increasing the expected tomato yield is to shift the efficiency frontier up and to the left; *i.e.*, there is a higher return level for a given level of risk. Conversely, if expected tomato yields are reduced, the frontier shifts down and to the right. Figure 4 shows a family of frontiers produced by varying the expected yield for all tomato activities. The data for the frontiers can be seen in Tables 6, 7, and 8. Again, these yields represent those in the most favorable planting and harvesting time periods and not average yields.

The impact of yield and thus management ability is quite dramatic. There are substantial variations in net return with specific high levels of risk, or conversely there are substantial variations in risk with specific high levels of net return. For a net return of $115,000, Frontier B attains a standard deviation of $34,000 and a coefficient of variation of 0.29 while Frontier C attains a standard deviation of $44,000 and a coefficient of variation of 0.38. This substantial difference in risk for the same net return is a direct result of the adjustments in farm organization allowed by a 4-ton per acre difference in tomato yield. Likewise, for the same level of risk, $44,000, net return changes from $115,000 (Frontier C) to $130,000 (Frontier B) as a result of a 4-ton per acre difference in tomato yield. Also, there is about $20,000 difference in maximum returns between the 18 and 22-ton yield levels with relatively little difference in risk.

There are substantial differences in tomato acreage in farm organizations for the different yield levels. Very small amounts of mechanically harvested tomato acreage remain in the solutions, even down to the point where land is rented out in order to achieve the least risk combination for a particular return level. This is observed in the farm organizations for Frontier B of Figure 4 for lower levels of return and risk. However, as discussed earlier, these small acreages are not practical. However, hand harvested tomato

TABLE 7.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier B (Tomatoes—22 T/A), Figure 4, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	130	135	140
Standard Deviation ($000's)	17	18	20	23	25	28	31	34	37	41	44	49	57
Coefficient of Variation	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.29	0.31	0.33	0.34	0.36	0.41
Farm Organization in Acres:													
Corn	210	189	136	116	114	114	114	114	145	240	245	294	479
Soybeans	116	152	224	286	348	348	325	316	244	115	1	0	0
Wheat	226	252	214	156	79	55	59	66	101	132	225	176	0
Mechanically Harvested Tomatoes	0	7	12	10	5	2	10	31	49	56	78	90	90
Hand Harvested Tomatoes	0	0	11	26	44	65	73	57	49	46	41	32	25
Cucumbers	0	0	3	6	11	16	18	14	12	11	10	8	6
Rented Out	48	0	0	0	0	0	0	0	0	0	0	0	0

acreages found in lower net return farm organizations for Frontier B are substantial. Small acreages of hand harvested tomatoes (15 to 30) are practical and are seen quite often in northwestern Ohio. These results show that hand harvested tomato acreage can be expanded considerably beyond what is common on most tomato producing farms before mechanical harvest becomes viable if yields are relatively high. However, with low yields, hand harvested tomatoes are not a profitable alternative and, except for the maximum net return farm organization, only the more profitable mechanically harvested enterprise remains in the solution (Table 8).

In analyzing the role of grain enterprises, it can be seen that the relative importance of wheat acreage is influenced by tomato yield. In fact, wheat acreage is unrealistically high for low levels of risk when compared to actual farm organizations in northwestern Ohio. This points up the importance of considering the total farm organization when dealing with risk. In some cases, risk may be decreased for a given level of return by choosing more risky crops for their high returns and combining them with low risk, low return crops. An example of this is the farm organization for $130,000 net return for Frontier B, Table 7. In order to reach this net return, high risk, high return tomatoes are combined with low risk, low return wheat to provide the least risky crop combination. Further, it is apparent from Table 7 that the role of wheat changes as return level changes. In the low risk, low return solutions, wheat allows diversification from corn and soybeans. At the high risk, high return solutions, wheat allows diversification from the high risk of tomatoes and high acreage of corn.

Specialty Crops vs. Grain Crops

The analysis in previous sections has shown that tomato acreage is feasible in farm organizations over a wide range of return-risk situations. Hand harvested tomatoes with high yield is a feasible enterprise even in relatively low return, low risk solutions. This raises questions about the return-risk situations in the absence of specialty crops. Frontier E of Figure 5 and Table 9 presents the return-risk opportunities available to a farmer who chooses not to produce specialty crops. This frontier can be compared to Frontier F derived for tomatoes yielding 24 tons per acre and Frontier A (taken from Figure 3) derived for tomatoes yielding 20 tons per acre. A comparison of Frontiers A and E shows that for tomato yields of 20 tons per acre, there is only a very slight increase in risk by shifting from a farm organization with specialty crops to a farm organization without specialty crops even at the $105,000 net return level. At this

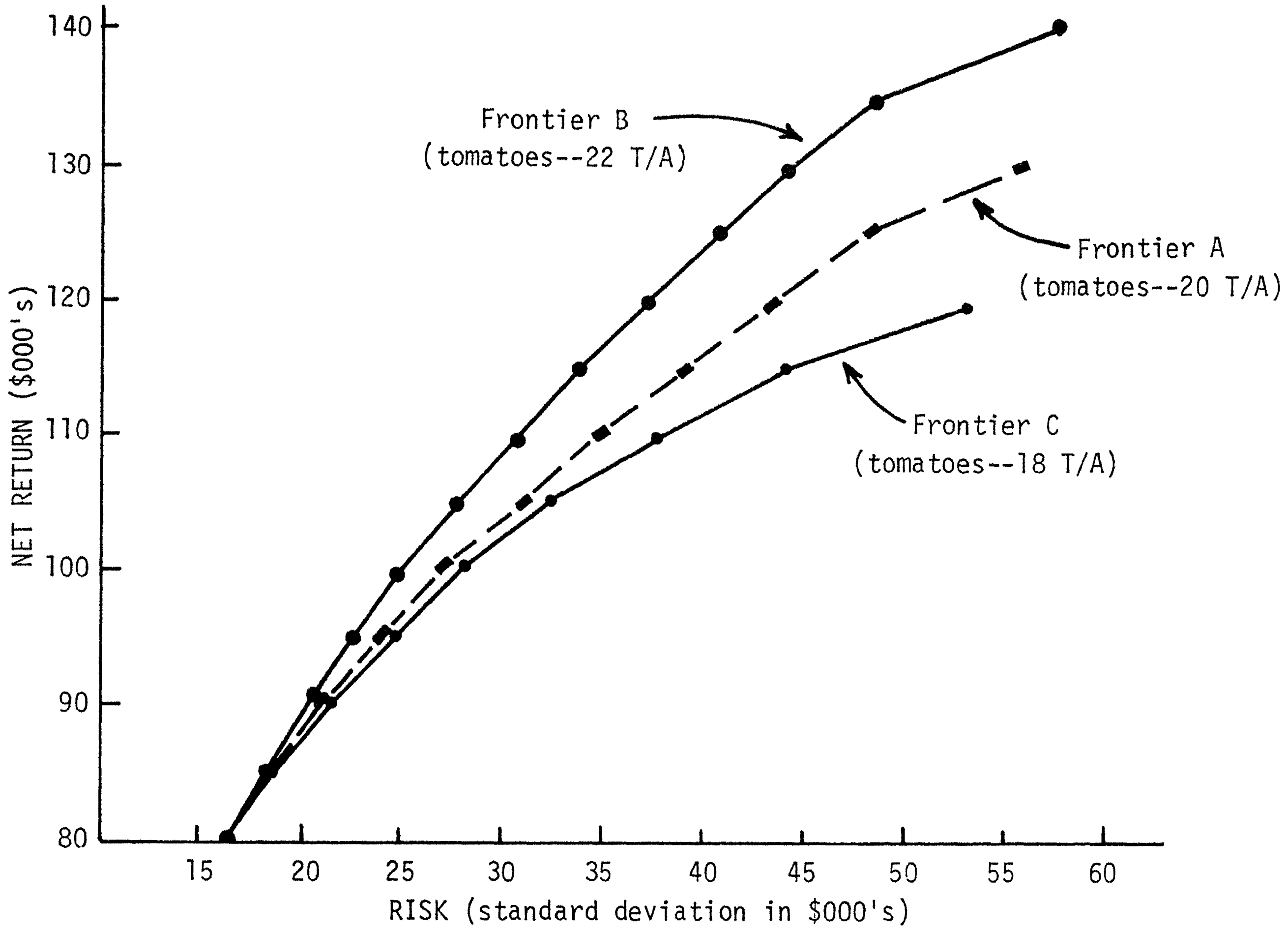

FIG. 4.—Efficiency Frontiers B (tomatoes—22 T/A), A (tomatoes—20 T/A), and C (tomatoes—18 T/A) for least risk farm organizations in Tables 6, 7, and 8, respectively.

TABLE 8.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier C (Tomatoes—18 T/A), Figure 4, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120
Standard Deviation ($000's)	17	19	22	25	28	32	38	44	53
Coefficient of Variation	0.21	0.22	0.24	0.26	0.28	0.31	0.34	0.38	0.44
Farm Organization in Acres:									
Corn	210	242	311	383	462	515	501	550	493
Soybeans	116	124	114	103	91	77	68	0	0
Wheat	226	233	175	114	46	0	0	0	0
Mechanically Harvested Tomatoes	0	0	0	0	0	8	31	50	74
Hand Harvested Tomatoes	0	0	0	0	0	0	0	0	26
Cucumbers	0	0	0	0	0	0	0	0	6
Rented Out	48	0	0	0	0	0	0	0	0

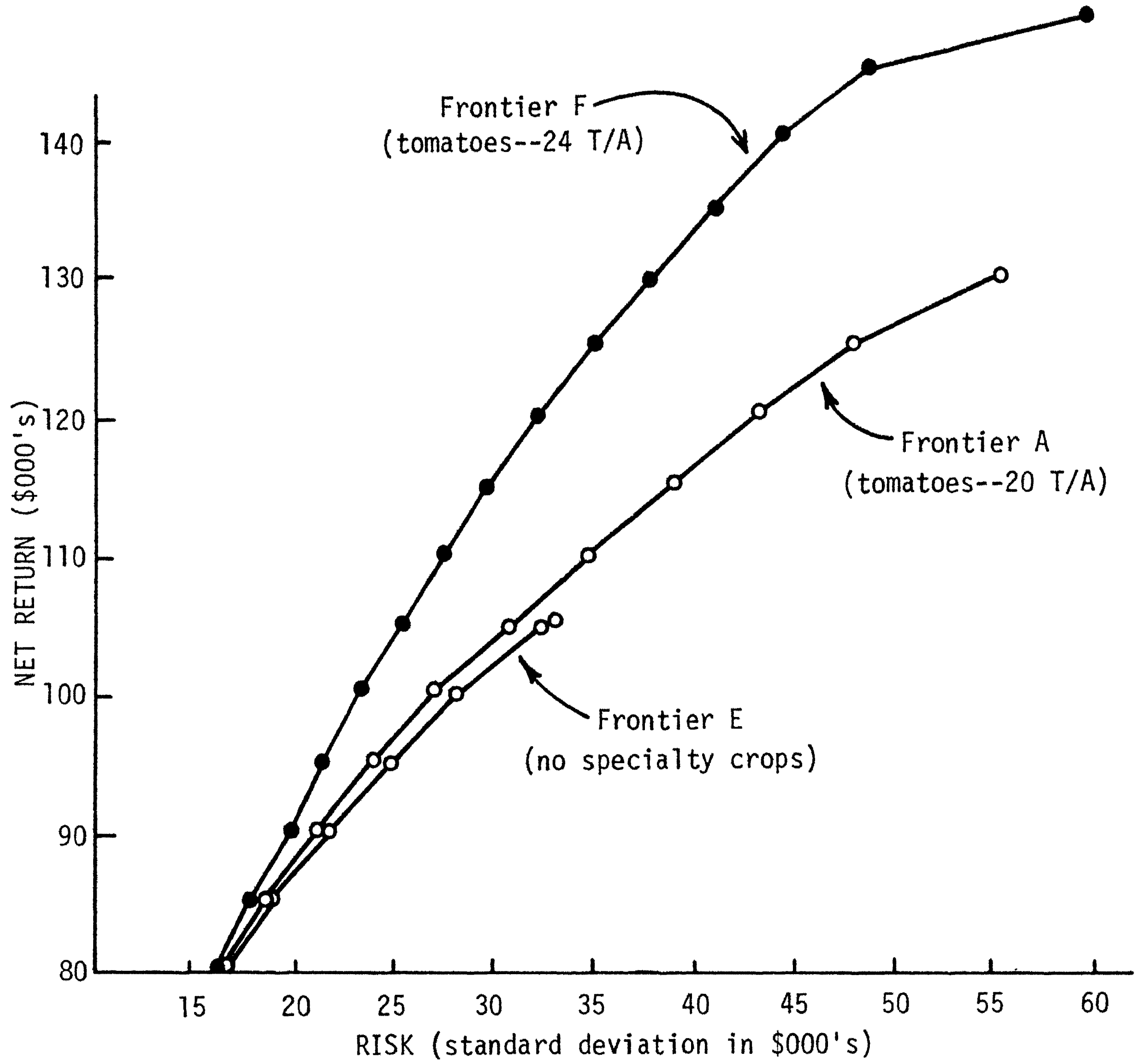

FIG. 5.—Efficiency Frontiers F (tomatoes—24 T/A), A (tomatoes—20 T/A), and E (no specialty crops) for least risk representative farm organizations in Tables 6, 9, and 10, respectively.

TABLE 9.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier E (No Specialty Crops), Figure 5, by Net Return.

Net Return ($000's)	80	85	90	95	100	105
Standard Deviation ($000's)	17	19	22	25	28	33
Coefficient of Variation	0.21	0.22	0.24	0.26	0.28	0.31
Farm Organization in Acres						
Corn	210	242	311	383	462	600
Soybeans	116	124	114	103	92	0
Wheat	226	233	175	114	46	0
Rented Out	48	0	0	0	0	0

return level, risk is at a maximum for grain crops as all 600 acres are in corn. This suggests that specialty crops are not a viable alternative for this representative farm for returns at or below this point with tomato yields less than 20 tons per acre. However, a return level above $105,000 can only be obtained by adding tomatoes even if the expected yield is only 20 tons per acre.

Tomatoes with a relatively high yield offer a realistic alternative to specialization in grain crops. With a 24-ton per acre yield, there is both the opportunity for less risk at return levels of $105,000 or less and opportunity for returns substantially above $105,000. Frontier F in Figure 5 shows that even with low return levels tomatoes offer significant reductions in risk relative to extensive production of grain crops. This suggests that farmers may choose to produce tomatoes even when they do not have the objective of relatively high return.

As discussed in the previous section, hand harvest of tomatoes is feasible at relatively low return, low risk situations if the tomato yield is relatively high. In Table 10, the importance of hand harvested tomatoes and cucumbers is clearly shown. The most important conclusion from Tables 9 and 10 is that tomato yield is a critical factor in consideration of lower risk alternatives to the corn intensive farm plans shown in Table 9. To the farmer now growing only grain crops, tomatoes at a 24-ton per acre yield offer the alternative of lower risk at his current return level or higher return at his current risk level. This can be accomplished without the relatively high tomato acreage that must accompany mechanical harvest.

RELATIONSHIP BETWEEN HARVESTING METHOD AND RISK

In the previous sections, it has been shown that both hand and mechanical tomato harvest systems are viable. However, conditions under which one or the other, or both, are viable must be carefully specified. Yield and return-risk levels are critical factors. This section gives a more detailed analysis of harvesting method.

Yield Differentials

To this point in the analysis, harvesting method was assumed not to influence tomato yield. However, there is some grower experience and observation to suggest that hand harvesting results in higher average yields than machine harvest. Therefore, a hand harvested yield of 22 tons per acre and a mechanically harvested yield of 20 tons per acre are now assumed. Results are shown in Frontier D of Figure 6. Frontiers B and A (reproductions of the frontiers in Figure 4) are derived under the assumption that hand and mechanically harvested acreage yields were equal.

TABLE 10.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier F (Tomatoes—24 T/A), Figure 5, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	130	135	140	145	149
Standard Deviation ($000's)	16	18	20	22	23	25	28	30	32	35	38	41	44	49	60
Coefficient of Variation	0.20	0.21	0.22	0.23	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.32	0.34	0.40
Farm Organization in Acres:															
Corn	146	130	117	126	114	114	114	114	114	114	114	114	180	245	471
Soybeans	157	207	251	257	309	332	308	289	119	119	119	119	54	87	0
Wheat	183	136	106	182	128	88	92	91	236	235	234	230	230	131	0
Mechanically Harvested Tomatoes	5	4	4	11	8	5	4	3	21	40	60	76	87	86	101
Hand Harvested Tomatoes	7	19	28	19	32	48	65	82	88	73	58	48	40	40	22
Cucumbers	2	5	7	5	8	12	16	20	22	18	17	12	10	10	5
Rented Out	100	100	87	0	0	0	0	0	0	0	0	0	0	0	0

A dramatic shift in acreage between mechanically harvested and hand harvested acreage occurs under the assumption that hand harvest acreage has a 2-ton per acre yield advantage (Table 11). No mechanically harvested tomato acreage exists below a return level of $125,000 for Frontier D. Mechanically harvested tomato acreage occurs at a substantial level (56 acres) for Frontier B at this level of net return (see Table 7).

Mechanically harvested tomato acreage exists only in the farm organizations for the last two points on Frontier D. These are extremely risky farm organizations. These results are consistent with comments of many farmers in the area concerning the risk associated with mechanically harvested tomatoes compared to that of hand harvesting. Apparently, farmer conclusions about relative risk of machine and hand harvest are very much influenced by expected average differences in yields with the two harvesting methods.

A surprising similarity in total acres of tomatoes can be seen over the entire range of net returns in Tables 7 and 11. For the 10 comparable net return levels, there is an average difference in total tomato acreage of only 3.9 acres. The largest difference is 9 acres which occurs at the high risk and high return level of $130,000. Also, the yield differential between hand and mechanical harvest causes the higher return farm organizations to be more risky at each return level than when the yield is 22 tons per acre for both harvesting methods (Figure 6). This is because of the increased importance of mechanically harvested acreage (and the lower yield associated with that acreage) at the high return levels. Again, the important relationship between risk and yield levels is shown. Lower yields with high return farm organizations cause relatively high levels of risk.

Machine vs. Hand Harvest

Combinations of machine and hand harvest have been common in the farm plans discussed thus far. However, some farmers may consider systems in which harvest is 100% mechanical or 100% hand.

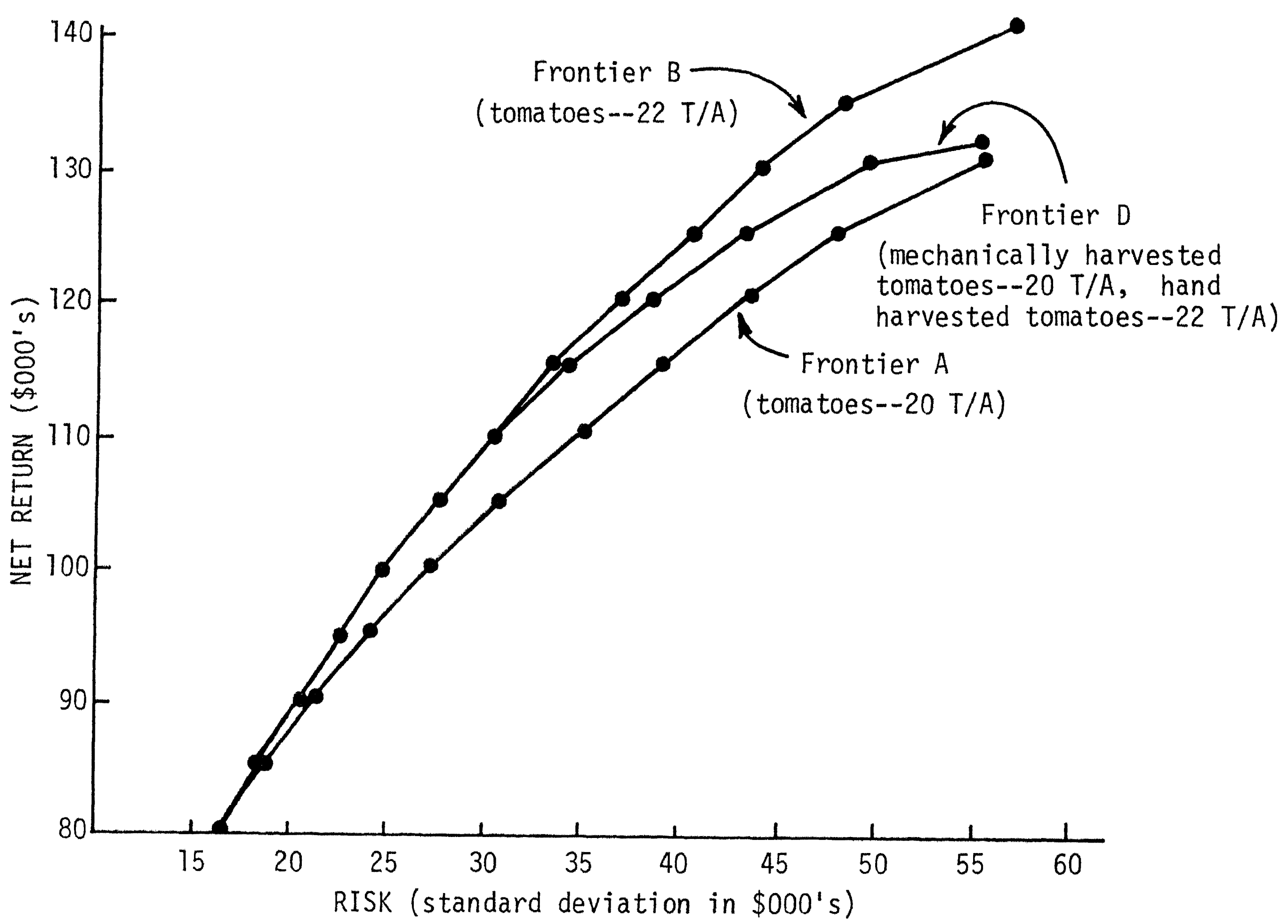

FIG. 6.—Efficiency Frontiers B (tomatoes—22 T/A), D (mechanically harvested tomatoes—20 T/A, hand harvested tomatoes—22 T/A), and A (tomatoes—20 T/A) for least risk representative farm organizations in Tables 6, 7, and 11, respectively.

Labor management problems are the most common cause of interest in an all-mechanical harvest system. The problems may be with availability of labor, regulations concerning the housing and employment of the workers, and/or the necessary labor management skills. Tomato growers or potential tomato growers may perceive the mechanical harvest as a way of avoiding these problems. On the other hand, some growers may want to consider a system with only hand harvest. This most likely reflects previous success with employment of migrant farm workers and/or the perceived unreliability of mechanical harvest due to weather and delivery restrictions imposed by processors.

Figure 7 shows the frontiers under three assumptions: a) hand harvested tomatoes only and 22 tons per acre (Frontier G), b) machine harvested tomatoes only and 20 tons per acre (Frontier H), and c) hand harvested tomatoes only and 20 tons per acre (Frontier J). Tables 12, 13, and 14 provide the farm organizations for the three frontiers in Figure 7.

Frontiers H and J allow comparison of hand only and machine only results under the assumption of equal yield (20 tons per acre). At this yield, mechanically harvested tomatoes have an advantage over hand harvested tomatoes because of the lower harvest cost. The result is fewer acres of tomatoes to attain given levels of net return. For example, at the $110,000 net return level, there are 68 acres of hand harvested tomatoes (Table 14) but only 46 mechanically harvested acres (Table 13). However, the risk level (coefficient of variation) is the same. There are also important differences in corn and soybean acreages as a result of the differences in tomato acreages. An additional difference is the net return and risk levels at which tomatoes become a viable part of the farm plan. With mechanical harvest, tomatoes come in with a feasible acreage at the $105,000 return level, $15,000 higher than with hand harvest.

Although it is interesting to note that Frontiers H and J cross in Figure 10, the most important observation is the very similar net return-risk tradeoffs with the two harvest methods when yields are equal. However, there is about $7,000 more return potential with mechanical harvest than hand harvest if the grower is willing to accept the additional risk.

Returning to the assumption of a 2-ton per acre yield advantage for hand harvest results in a frontier substantially different from Frontiers H and J (Figure 7). Comparing Frontier G (derived for 22-ton per acre tomatoes harvested by hand) and Frontier H (derived for 20-ton per acre tomatoes harvested by machine) shows important differences in risk at the higher net return levels (Tables 12 and 13). The higher tomato yield with hand harvest results in re-

TABLE 11.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier D (Mechanically Harvested Tomatoes—20 T/A, Hand Harvested Tomatoes—22 T/A), Figure 6, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	130	132
Standard Deviation ($000's)	17	18	20	23	25	28	30	34	39	43	50	56
Coefficient of Variation	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.30	0.32	0.35	0.38	0.42
Farm Organization in Acres												
Corn	210	222	196	168	137	114	175	245	308	405	400	483
Soybeans	116	140	203	267	339	378	270	188	106	0	75	0
Wheat	226	234	181	127	66	26	56	58	60	63	0	0
Mechanically Harvested Tomatoes	0	0	0	0	0	0	0	0	0	0	49	83
Hand Harvested Tomatoes	0	3	16	30	46	65	79	88	100	100	61	27
Cucumbers	0	1	4	8	11	16	20	22	25	25	15	7
Rented Out	48	0	0	0	0	0	0	0	0	0	0	0

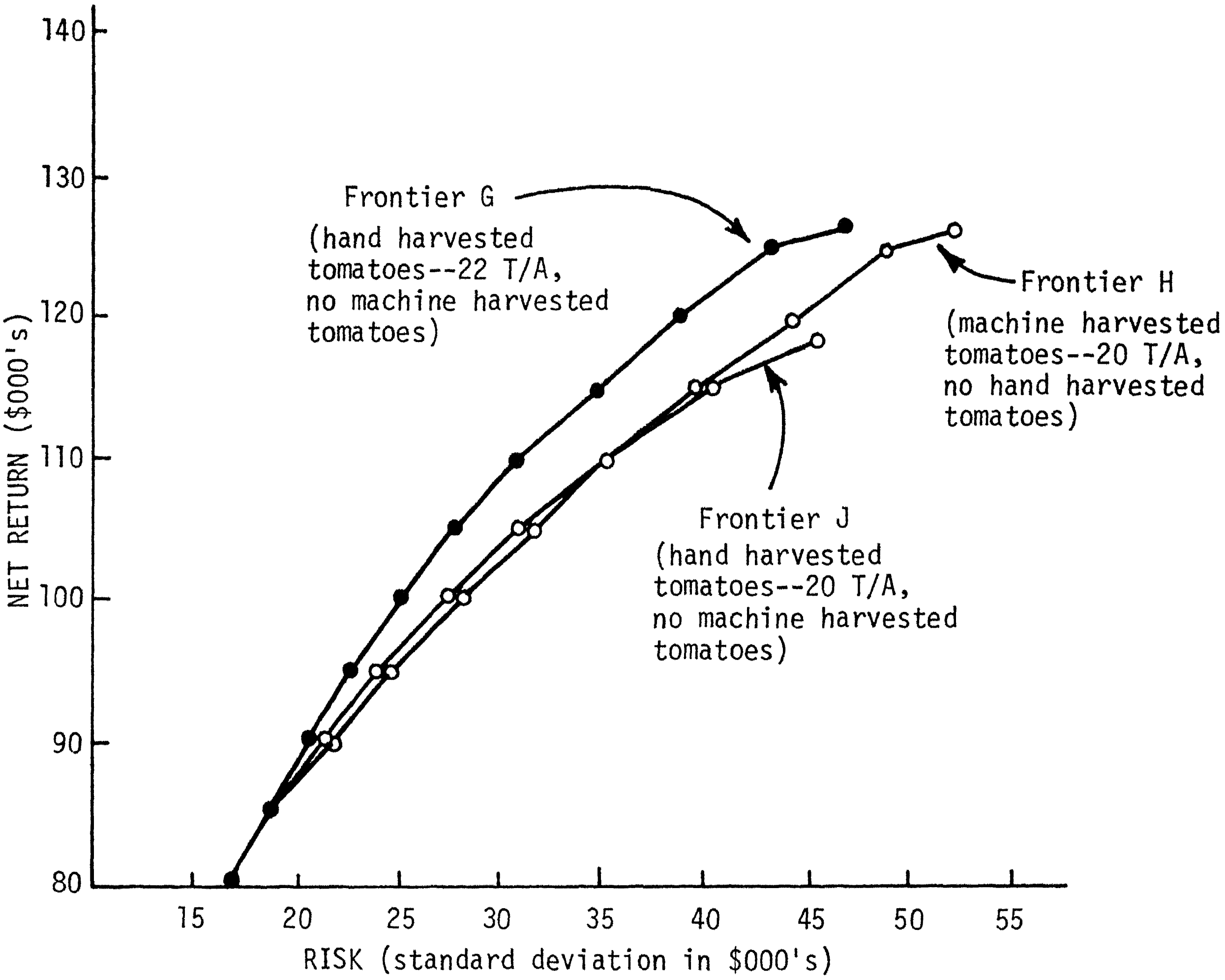

FIG. 7.—Efficiency Frontiers G, H, and J for least risk representative farm organizations in Tables 12, 13, and 14, respectively.

TABLE 12.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier G (Hand Harvested Tomatoes—22 T/A, No Machine Harvested Tomatoes), Figure 7, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	127
Standard Deviation ($000's)	17	18	20	23	25	28	31	34	38	43	47
Coefficient of Variation	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.30	0.32	0.34	0.37
Farm Organization in Acres:											
Corn	210	222	196	168	137	114	175	245	245	390	462
Soybeans	116	140	203	267	339	378	270	188	157	9	0
Wheat	226	234	181	127	66	26	56	58	62	62	0
Hand Harvested Tomatoes	0	3	16	30	46	65	79	88	109	111	111
Cucumbers	0	1	4	8	11	16	20	22	27	28	28
Rented Out	48	0	0	0	0	0	0	0	0	0	0

turn opportunities equal to those with mechanical harvest. A comparison of Tables 12 and 13 shows that the hand harvested tomato acreage is considerably greater than the mechanically harvested acreage for all farm organizations along the frontier. Even with the increased acreage for hand harvest and the corresponding cucumber acreage, the risk for the total farm organization for each level of return is less.

Although greater than 2-ton yield differences were not analyzed, such differences would likely result in even greater differences in risk at the higher net return levels. In addition, the difference in risk between these two frontiers would probably be greater if the data used in the analysis more accurately reflected the true risks associated with harvesting tomatoes by machine. The time series data used for mechanically harvested tomato yields may understate the risk associated with mechanically harvested tomatoes because migrant labor was employed on an emergency basis in 2 years when machines could not harvest all the acreage due to wet field conditions. This was possible only because there happened to be surplus migrant labor in the area. Thus, the risk of reduced yield due to machine inadequacy would likely increase if fewer migrant workers were available in northwestern Ohio and growers were limited to mechanical harvest even during the most weather adverse years.

TABLE 13.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier H (Machine Harvested Tomatoes—20 T/A, No Hand Harvested Tomatoes), Figure 7, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	126
Standard Deviation ($000's)	17	19	22	25	28	31	35	39	44	48	52
Coefficient of Variation	0.21	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.39	0.41
Farm Organization in Acres:											
Corn	210	242	311	311	305	299	278	318	474	446	515
Soybeans	116	124	114	142	176	212	258	225	69	76	0
Wheat	226	233	175	137	98	57	17	0	0	0	0
Mechanically Harvested Tomatoes	0	0	0	9	20	32	46	57	57	78	84
Rented Out	48	0	0	0	0	0	0	0	0	0	0

TABLE 14.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier J (Hand Harvested Tomatoes—20 T/A, No Machine Harvested Tomatoes), Figure 7, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	119
Standard Deviation ($000's)	17	19	21	24	27	31	35	40	45
Coefficient of Variation	0.21	0.22	0.23	0.25	0.27	0.29	0.32	0.35	0.38
Farm Organization in Acres:									
Corn	210	221	118	186	245	273	345	487	474
Soybeans	116	144	223	274	278	262	170	22	0
Wheat	226	231	164	99	33	0	0	0	0
Hand Harvested Tomatoes	0	4	21	33	35	53	68	73	101
Cucumbers	0	1	5	8	9	13	17	18	25
Rented Out	48	0	0	0	0	0	0	0	0

ANALYSIS OF DELIVERY RESTRICTIONS

Wet weather is not the only limitation to mechanical harvest. An interrelated problem stems from the delivery quotas specified in production contracts. Mechanical harvesters easily fill the daily delivery quotas during favorable operating conditions. Therefore, it is important to analyze how delivery restrictions affect mechanically harvested tomato acreage in optimal solutions along the efficiency frontiers. Figure 8 represents farm organizations derived under three assumptions: a) no delivery quotas (Frontier K), b) a 1-ton per acre per day quota (Frontier A reproduced from Figure 3), and c) an 0.6-ton per acre per day quota (Frontier L). Tables 6, 15, and 16 provide the data and farm organizations for these frontiers.

The 0.6-ton per acre per day delivery quota excludes mechanical harvest (Table 16). But there is substantial acreage of hand harvested tomatoes in the higher net return farm plans. This reflects the advantages of multiple picking of the same acreage and hand harvest feasibility even in very wet field conditions. However, there is a substantial reduction in the net return potential relative to the 1-ton per acre per day or no quota situation. It can also be seen in Figure 8 that the risk level is substantially higher at the $110,000 and above net return level with the restrictive quota. This is due to limited enterprise diversification at these net return levels with the 0.6-ton per acre per day quota.

A comparison of Frontiers K and A shows that delivery quotas are restrictive, but that the reduction in return (or increase in risk) is not substantial for a 1-ton per acre per day quota relative to no delivery quota. Table 15 shows that mechanically harvested tomatoes come in at rather low return-risk farm organizations when there are no delivery quotas. However, as previous results have shown, the lower return-risk farm organizations including specialty crops are negligibly less risky than those derived exclusively for grain enterprises up to a return level of $105,000. However, mechanically harvested acreage is significant at every level of returns above $105,000. It can also be seen that diversification with hand harvested tomatoes occurs on the upper portion of this frontier.

TABLE 15.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier K (No Delivery Quota), Figure 8, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	120	125	130	132
Standard Deviation ($000's)	17	19	21	24	26	29	33	36	40	45	50	54
Coefficient of Variation	0.21	0.22	0.23	0.25	0.26	0.28	0.30	0.31	0.34	0.36	0.38	0.41
Farm Organization in Acres:												
Corn	210	182	118	114	138	245	245	259	267	360	419	479
Soybeans	116	156	245	242	267	223	256	278	259	152	77	0
Wheat	226	254	205	211	153	99	57	10	0	0	0	0
Mechanically Harvested Tomatoes	0	8	14	33	34	33	43	52	61	61	68	68
Hand Harvested Tomatoes	0	0	14	0	6	0	0	0	10	22	28	42
Cucumbers	0	0	4	0	1	0	0	0	3	6	7	11
Rented Out	48	0	0	0	0	0	0	0	0	0	0	0

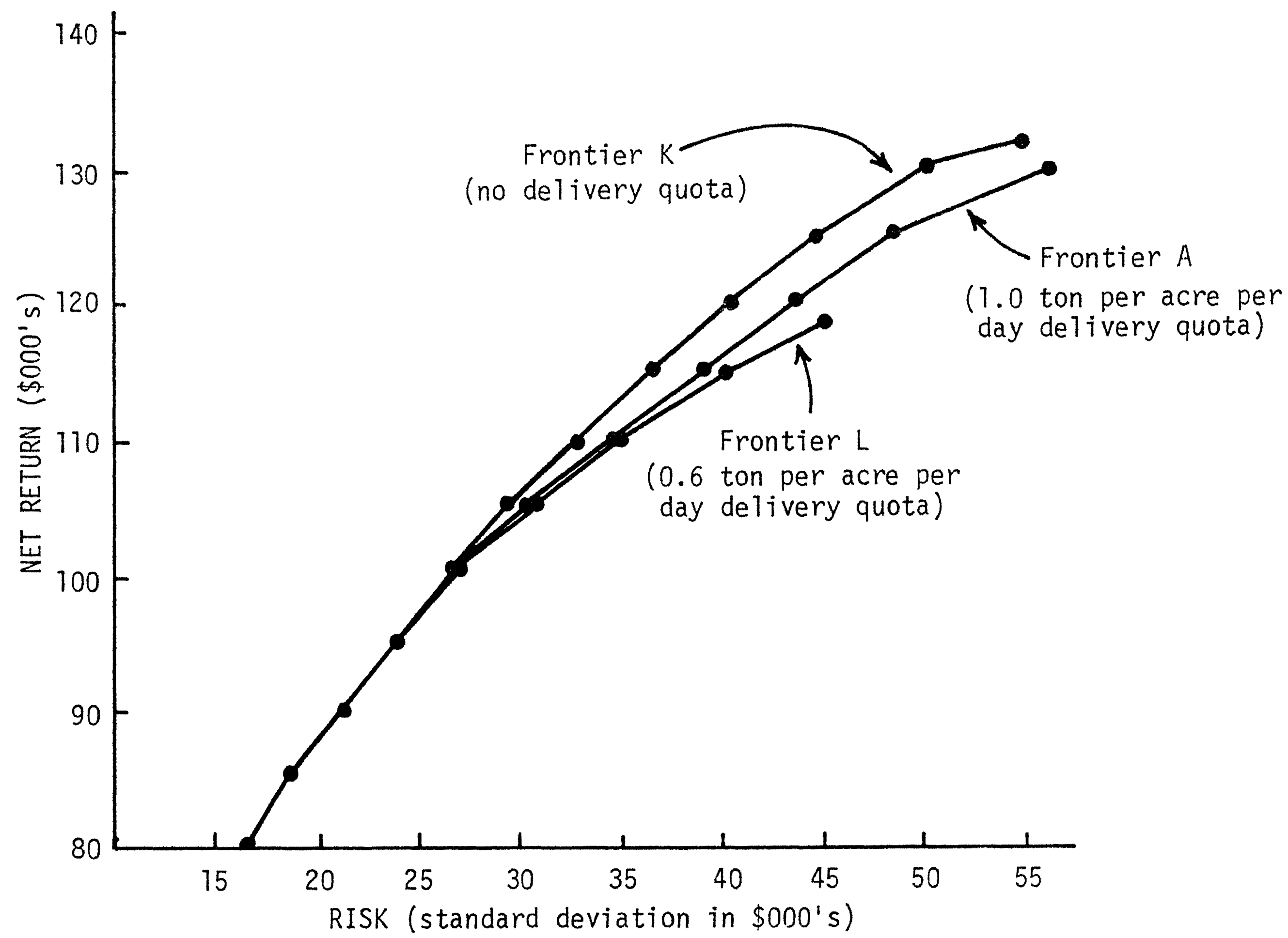

FIG. 8.—Efficiency Frontiers K, A, and L for least risk representative from organizations in Tables 15, 6, and 16, respectively.

TABLE 16.—Standard Deviations, Coefficients of Variation, and Minimum Risk Farm Organizations for Frontier L (0.6 T/A/Day Delivery Quota), Figure 8, by Net Return.

Net Return ($000's)	80	85	90	95	100	105	110	115	119
Standard Deviation ($000's)	17	19	21	24	27	31	35	40	45
Coefficient of Variation	0.21	0.22	0.23	0.25	0.27	0.29	0.32	0.35	0.38
Farm Organization in Acres:									
Corn	210	221	187	186	245	273	345	487	474
Soybeans	116	144	223	274	178	262	170	22	0
Wheat	226	231	164	99	33	0	0	0	0
Mechanically Harvested Tomatoes	0	0	0	0	0	0	0	0	0
Hand Harvested Tomatoes	0	4	21	33	35	53	68	73	101
Cucumbers	0	1	5	8	9	13	17	18	25
Rented Out	48	0	0	0	0	0	0	0	0

SUMMARY

The emphasis of this study is on the tradeoffs between risk and returns. Within an enterprise combination framework, the analysis was concentrated on the association between tomato acreage and tomato harvesting method, yields, yield differentials between harvesting methods, and delivery quotas.

The coefficient of variation (variation in annual return per dollar of expected return) was used as a basis for comparing the risk among individual enterprises. Based on time series data from individual farmers, cucumbers were found to be the riskiest enterprise. Hand harvested tomatoes were nearly as risky as cucumbers and more risky than mechanically harvested tomatoes. Grain crops were considerably less risky than any of the specialty crops. The variation in annual net return for mechanically harvested tomatoes was greater than that for hand harvested tomatoes but the coefficient of variation (risk) was lower. This is due to the greater expected return associated with mechanically harvested tomatoes when yields are equal. A yield advantage of slightly less than 4 tons per acre for hand harvested tomatoes is necessary to make the risk equal for the two harvest methods.

Return-risk tradeoffs for different enterprise combinations were investigated on a 600-acre representative farm. In particular, factors affecting tomato acreage were examined. Results clearly indicate that tomato yield has a major impact on the tomato acreage found in the minimum risk farm organizations derived. With an 18-ton per acre yield, tomatoes do not enter farm organizations with a return level of $105,000 above variable costs. At this yield level, significant tomato acreage occurs in only three farm organizations for return levels above $110,000. For tomato yields of 22 tons per acre, tomatoes occur in farm organizations for returns as low as $85,000. The results indicate that farm organizations derived for low return and risk levels do not contain tomatoes when yields are less than 20 tons per acre. However, if tomato yields are greater than 20 tons per acre, minimum risk farm organizations do contain tomatoes even for low return and risk levels. Also, high return and risk farm organizations include substantial acreages of tomatoes for all tomato yields greater than 16 tons per acre.

There are significant differences in return and risk between farm organizations derived for different expected tomato yields. High yield levels result in significantly increased return and reduced risk farm organizations. An increase in yield from 18 tons per acre to 22 tons per acre results in a $10,000 reduction in the standard deviation for the same net return of $115,000. Likewise, for this same yield increase and a risk level of $44,000, net return increases by $15,000.

The return and risk potentials with exclusive production of grain crops and combinations of grain and specialty crops were compared. Maximum return from the exclusive production of grain crops was $105,000. Net returns increased substantially with the addition of specialty crops. Maximum net returns for tomato yields of 20 and 24 tons per acre were $130,000 and $149,000, respectively. With tomato yields less than 20 tons per acre, there is little difference in the risk at equal return levels for farm organizations with and without specialty crops. However, an important finding was that for yields of 24 tons per acre or better, tomatoes do present an opportunity for diversification to a farm organization with less risk than that associated with an equivalent return earned by producing only grain crops. For a net return level of $100,000, farm organizations with tomatoes yielding 24 tons per acre had a standard deviation of $23,000, which was $5,000 less than the standard deviation for the least risky farm organization exclusively producing grain crops.

Factors affecting the decision between harvesting by hand and harvesting by machine were also investigated. Results indicate that the amount of hand and mechanically harvested tomatoes is very much influenced by the yield differences between the two harvesting methods. The model was initially allowed to produce any combination of hand and mechanically harvested tomatoes under the assumption that tomato yields for the two harvesting methods were equal. Under this assumption, hand harvested tomatoes generally dominate tomato acreage over middle portions of the frontier while mechanically harvested tomatoes generally dominate tomato acreage in higher return and risk farm plans. However, with a 2-ton per acre yield advantage for hand harvest, hand harvested tomato acreage dominates more of the efficiency frontier while mechanical harvest dominates only the most risky farm organizations.

Risk-return comparisons were also made between farm organizations with hand harvested tomatoes excluded and with mechanically harvested tomatoes excluded. Mechanically harvested tomatoes provide more return potential than hand harvested tomatoes (including the cucumbers produced with the hand harvested tomatoes). This result was derived under the assumption that the yields for the two harvesting methods were equal. Under this assumption, mechanically harvested tomatoes are more profitable than hand harvested tomatoes because of the lower harvesting costs. Results changed significantly under the assumption that hand harvested acreage had a 2-ton per acre yield advantage over mechanically harvested acreage. For this yield relationship, it was found that farm organizations including hand harvested tomatoes result in less risk than farm organizations including mechanically harvested tomatoes. Also, hand harvested tomatoes with a 2-ton yield advantage will allow the farm to achieve the same return levels as mechanically harvested tomatoes. However, under both yield assumptions, more hand than mechanically harvested acreage was necessary to attain a specified return level.

The effect of delivery quotas on the return and risk potential for farm organizations including mechanically harvested tomatoes was also analyzed. A delivery quota of 0.6 ton per acre per day eliminated mechanically harvested tomatoes from all farm plans. Unrestricted deliveries allowed mechanically harvested tomato acreage to displace hand harvested tomatoes over the middle range of net returns where hand harvested tomatoes dominated with the assumption of a 1-ton per acre per day quota. A 1-ton per acre per day delivery quota was more restrictive than unrestrictive delivery, but the difference was small in terms of return or risk.

IMPLICATIONS

Expected tomato yield has surfaced repeatedly as a major variable in the enterprise selection problem. Farmers should take extra care in evaluating expected yields when making decisions concerning tomato production. Good managers who expect tomato yields of more than 20 tons per acre should consider producing tomatoes. The influence of yields on the competitiveness of tomatoes relative to grain crops in farm plans emphasizes the importance of tomato production practices.

Comparisons of mechanically harvested tomatoes and hand harvested tomatoes also show the importance of expected yields for the two harvesting methods. Mechanically harvested tomatoes have greater net return as long as hand harvested tomatoes have less than a 4-ton per acre yield advantage. However, hand harvested tomatoes and cucumbers combine to produce less risky farm organizations than farm organizations containing mechanically harvested tomatoes. With a yield advantage of 2 tons per acre, hand harvested tomatoes combined with cucumbers result in more efficient farm organizations than those containing mechanically harvested tomatoes.

There is potential for expanding tomato acreage as a farmer's ability to assume risk grows. Small acreages of tomatoes can be included in relatively low risk, low return farm organizations. These tomatoes can even be mechanically harvested if yields are high. As tomato acreage expands, there are alternatives for either hand or mechanical harvest and several different combinations of hand and mechanical harvest.

Because yields are important, growers with high yields are likely to continue producing tomatoes in spite of the risk. They can diversify into tomatoes with less risk than if they grew only corn, soybeans, and wheat to achieve a similar income. Good managers also have the opportunity to increase their acreage in specialty crops and attain return levels far above those attainable by producing only grain crops. This implies that there are high payoffs to good management in tomato production.

Based on the importance of expected yields in the analysis, there will be great demand for and excellent return to the resources necessary for high yielding tomato enterprises. These resources include management ability, technological know-how, and land resources. Thus, there will be upward pressure on prices for well-drained, good quality land. There will also be heavy demand for technological know-how. Good managers will be attracted to tomato production because of the high returns to management ability in tomato production.

A combination of both hand and machine harvested tomatoes is profitable under a variety of situations, even though the entire benefits derived from a combination of the two harvesting methods are not captured in the model. This implies that there may be a definite trend toward farm organizations which contain a combination of the two harvesting methods. This trend would result in decreased employment of migrant farm workers but increased opportunities for them to work with tomato harvesting machines.

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Northwestern Branch, Hoytville, Wood County: 247 acres

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